Off-Highway Thermal Management/Systems Efficiency Technologies

Cooling Fan and System Performance and Efficiency Improvements

by

Ron Dupree
Caterpillar, Inc. Machine Research
April 19, 2006

Cooling Fan and System System Performance and Efficiency Improvements

21CTP Technical Goal: **Increase efficiency of cooling system components**

Project Objectives

• Develop cooling system fans and fan systems that will allow off-highway machines to meet Tier 3 emissions regulations and reduce spectator sound levels with improved fuel efficiency, and within the functional constraints of machine size.

FY 2005 Focus

• Complete design of large high performance axial fan

• Complete performance and sound tests of 'aerodynamic' fan shroud

• Complete lab development of radiator air filtration system

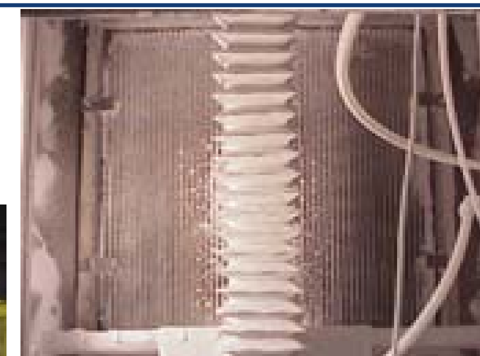
Planned Duration

June 2002 to July 2005

DOE Funding/Industry Cost Share

FY04: $377K FY05: $138K

A moving, high velocity 'air knife' used to clean fine inorganic debris from the face of a radiator



'Aeroshroud' concept can change the point of fan stall, and dramatically change fan performance over a narrow range.

Principal Investigators

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Technology Development Manager
Sid Diamond, DOE/OFCVT
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Accomplishments

Accomplishment 1 – Demonstrated 5% flow (goal of 10%) improvement and 10% efficiency improvement (met goal) of large axial fan

Accomplishment 2 – Demonstrated ability to meet performance goals of 'aerodynamic' fan shroud over a narrow operating range. Noise level of fan reduced by up to 2dB

Accomplishment 3 – Fan CFD modeling guide completed to provide 5% accuracy

Accomplishment 4 – Small fan performance demo terminated when unable to meet performance goal

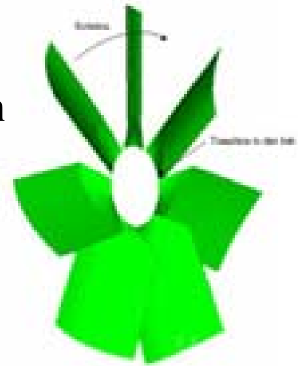
Accomplishment 5 – Fan drive development terminated when unable to meet performance goal

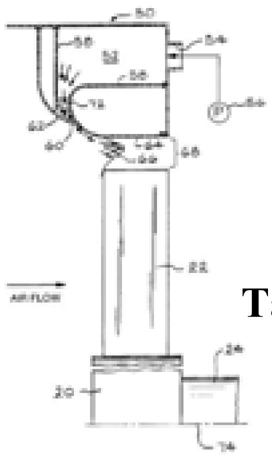
Accomplishment 6 – Demonstrated 'air knife' concept to provide fine debris filtration for high performance radiators

Project ID/Agreement ID	Program Structure	Sub-Program Element	R&D Phase	Date
16037	Vehicles Systems	HV Systems Optimization	Exploratory Research	19 April 2006

Cooling Fan and System System Performance and Efficiency Improvements

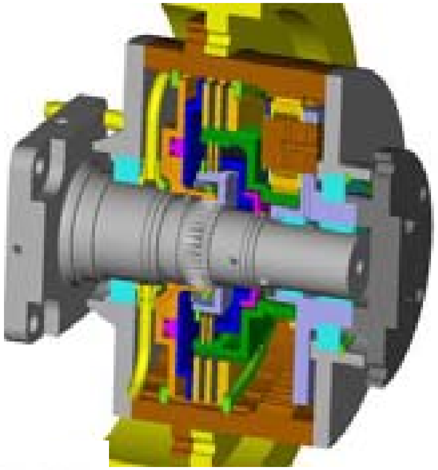
Task 1 – Large High Performance Axial Fan



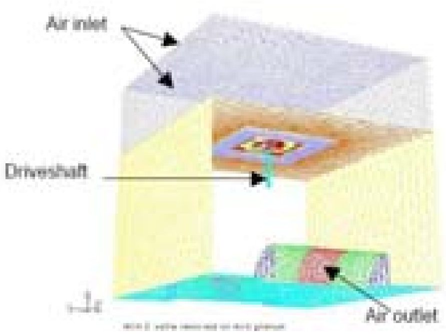


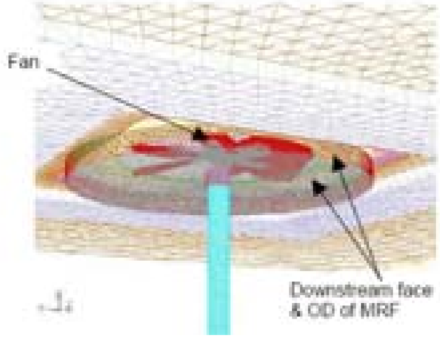
Task 2 – “Aeroshroud”

Task 4 – Small High Performance Fan



Task 5 – High Efficiency Variable Speed Fan Drive





Task 3 – Fan Performance Modeling

Task 6 – Radiator Dust Filtration

Partners in Development activities

Task 1 – Engineered Cooling Systems (Now Horton), Carmel, Ind.

Task 2 – Michigan State University & Engineered Cooling Systems

Task 3 – Michigan State University & Fluent, Inc

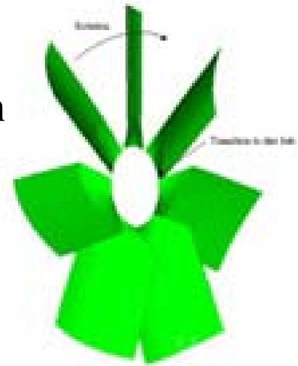
Task 4 – CoreTech Systems, East Greenich, RI (nylon development)

Task 6 – Innoventor, Inc, St. Louis, Mo.

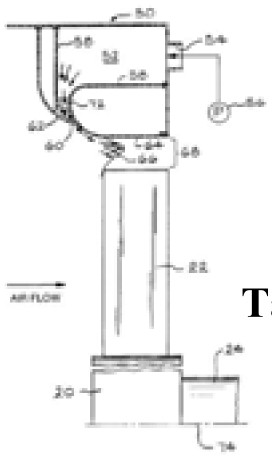
And many departments within Caterpillar, Inc.

Cooling Fan and System System Performance and Efficiency Improvements

Task 1 – Large High Performance Axial Fan

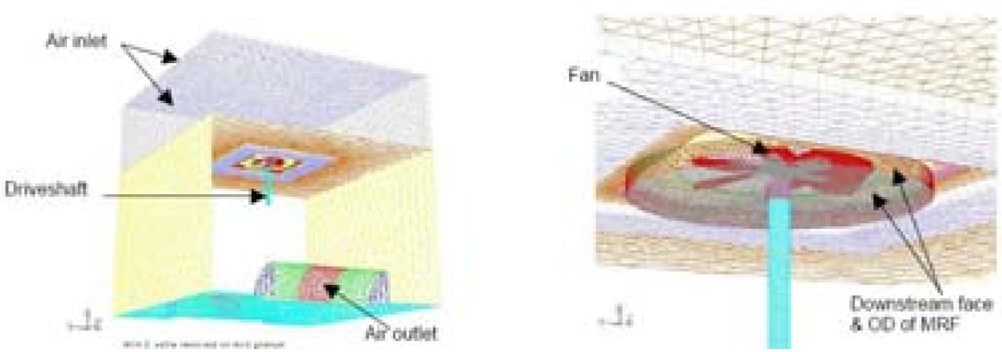


Goals:
10% more flow ***demonstrated 5%***
10% higher efficiency ***demonstrated 10%***



Task 2 – "Aeroshroud"

Goals:
10% more flow ***demonstrated 10+% over a narrow operating range***
10% higher efficiency ***demonstrated no change in efficiency***
5dB noise reduction ***demonstrated 0 to 2dB***



Goals:
Predict flows within 5% of measured values
Met goal

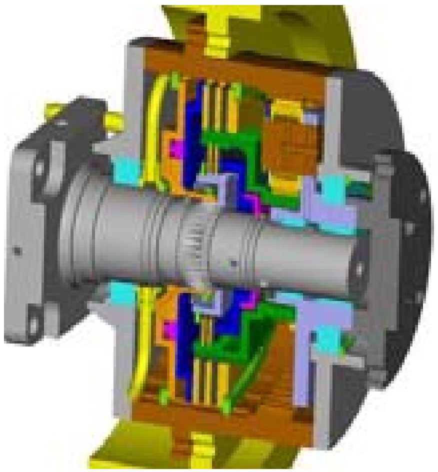
Task 3 – Fan Performance Modeling

Individual task goals

Cooling Fan and System System Performance and Efficiency Improvements

Task 4 – Small High Performance Fan

Goals:
No flow improvements, but at 75% of input power. ***Demonstrated 82% with no downstream obstructions.***
5dB quieter at constant flow. ***Demonstrated no change in noise, due to flow loss when mounted close to engine.***



Task 5 – High Efficiency Variable Speed Fan Drive

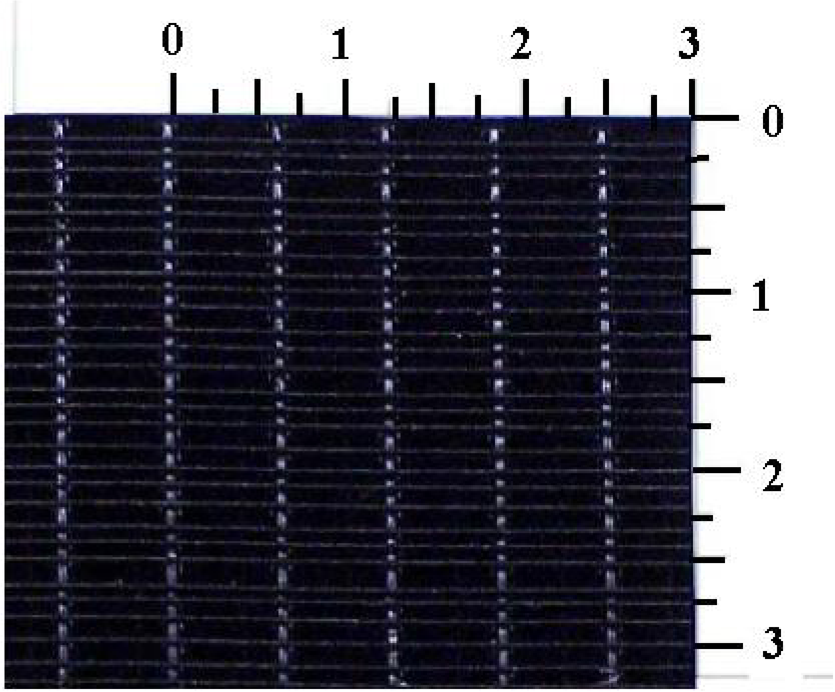
Goals:
95%+ efficiency at max ratio
Losses at lower speed no greater than losses at max ratio. ***Met goal at max ratio, could not meet goal at all operating points. Work terminated at initial design.***

Task 6 – Radiator Debris Filtration

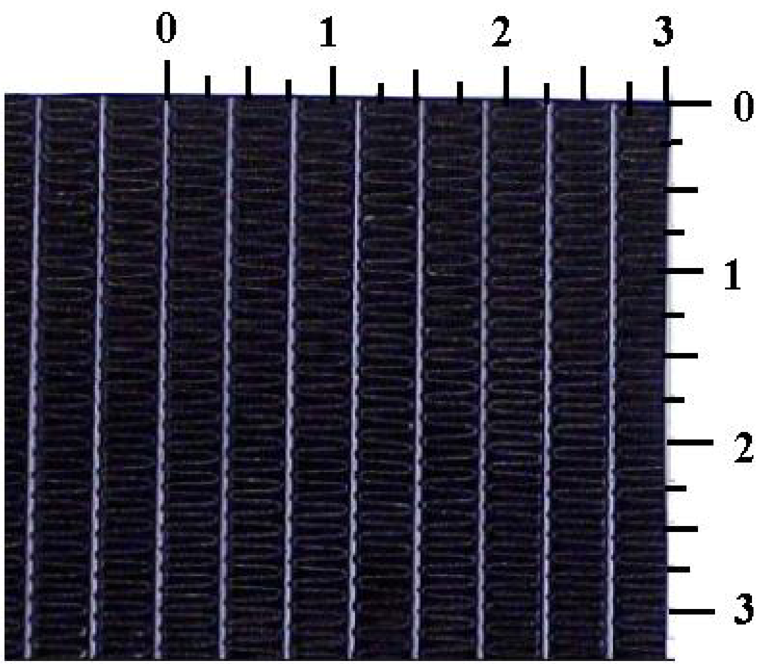
Goals:
Develop an effective radiator air filtration system. ***Demonstrated in lab environment.***

Individual task goals

Cooling Fan and System System Performance and Efficiency Improvements



Off-Highway radiator 9 flat fins/inch to resist fouling



On-Highway radiator 16 to 18 fins/inch with louvers to maximize performance

Off Highway Radiators Have Lower Performance than On-Highway Radiators

Cooling Fan and System System Performance and Efficiency Improvements

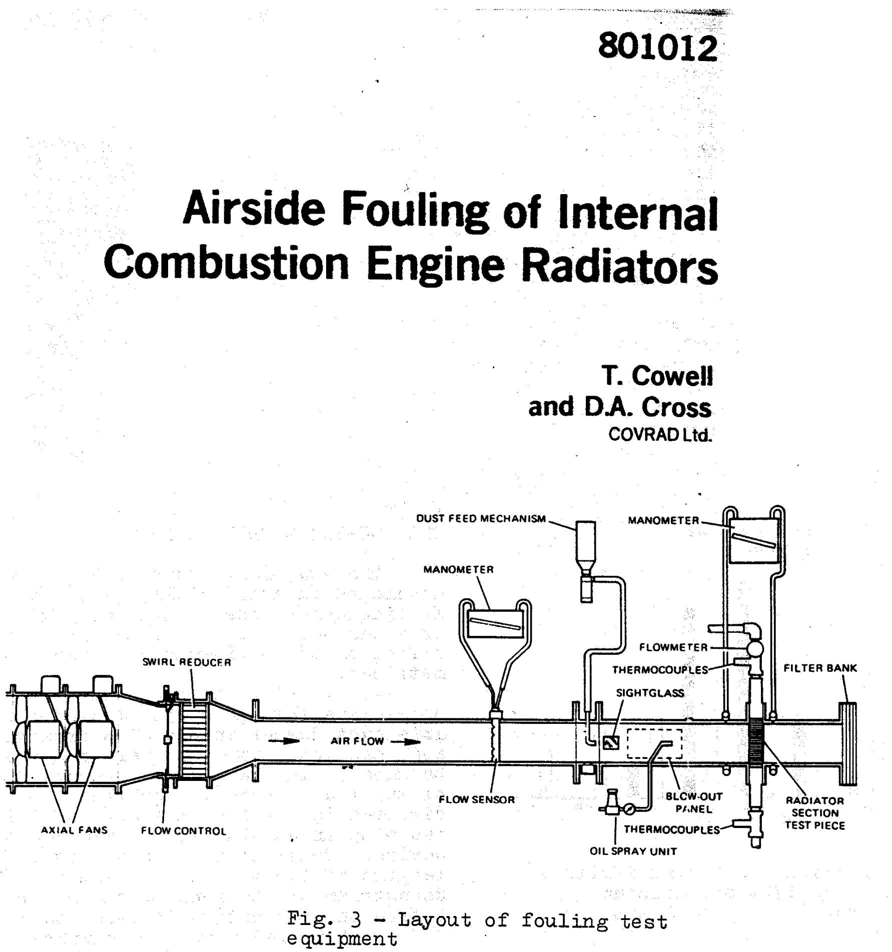
Organic debris is large – blocks face of core.
Can be filtered with inlet screens

Inrganic debris is small – less than 50 microns. Significant fouling media for dense cores.

A single filtration system cannot provide protection against all debris types

Task 6 – Radiator Dust Filtration

Cooling Fan and System System Performance and Efficiency Improvements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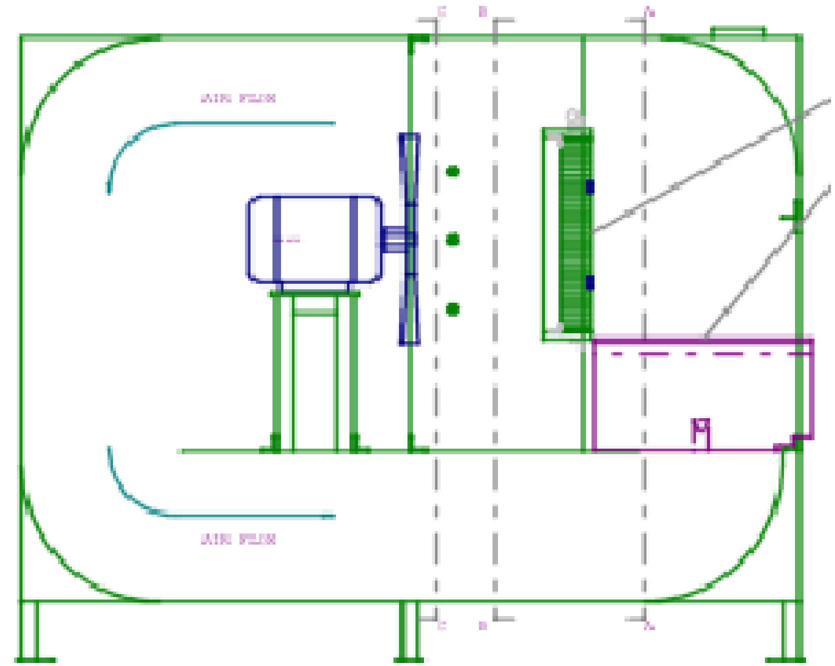
Airside Fouling of Internal Combustion Engine Radiators

T. Cowell
and D.A. Cross
COVRAD Ltd.

Fig. 3 - Layout of fouling test equipment

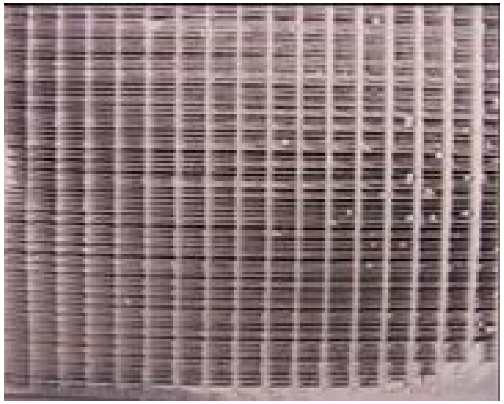


Industrial example of radiator fouling test at COVRAD using single pass test with fine test dust

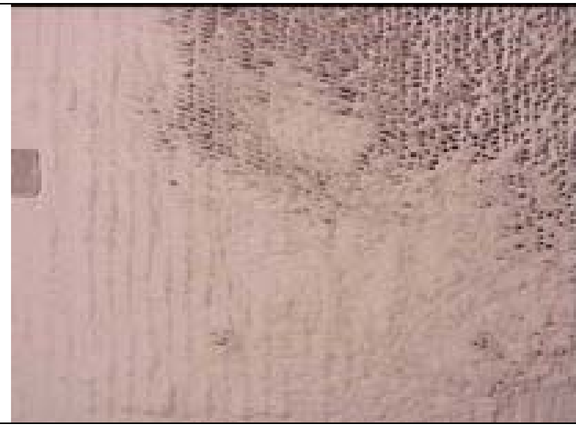
Recirculating dust test facility at Caterpillar. Fan draws air through the radiator. Dust is injected to the left of the fan in this schematic

Task 6 – Radiator Dust Filtration

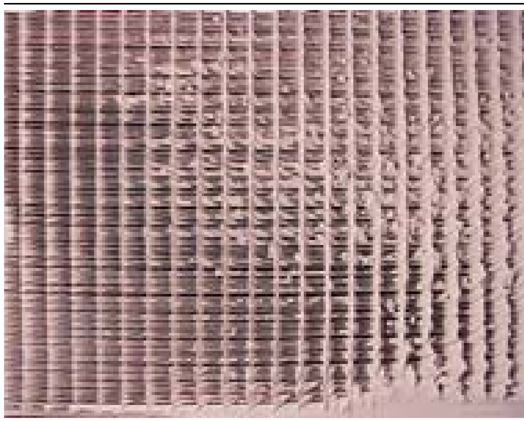
Cooling Fan and System System Performance and Efficiency Improvements



Baseline core at 21 hours



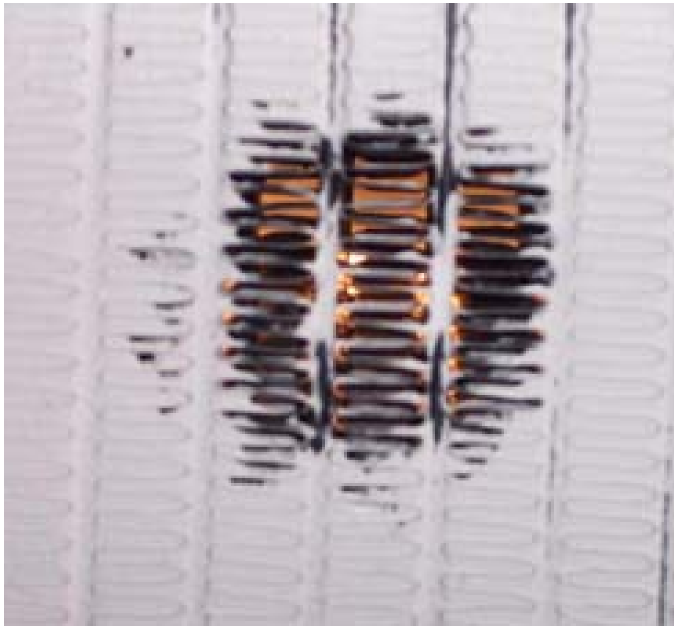
High performance truck core at 24.5 hours



Baseline at 36 hours

High performance truck core at 39 hours

Back to back debris fouling results of baseline vs truck core



Closeup photo of truck core showing depth of debris fouling

Task 6 – Radiator Dust Filtration

Cooling Fan and System System Performance and Efficiency Improvements

Technologies Evaluated in Conjunction with *Innoventor, Inc.* of St. Louis, Mo.

Electrical grounding of cores to prevent static buildup

Application of 24V DC to cores

Application of 24V AC to cores

High pressure air and ionization blown on cores

Ultrasonic source in airstream

(+)ions and (-)ions introduced in airstream

Vibration applied to core

High Voltage 20,000 V applied to core

Moving media bed filter upstream of core

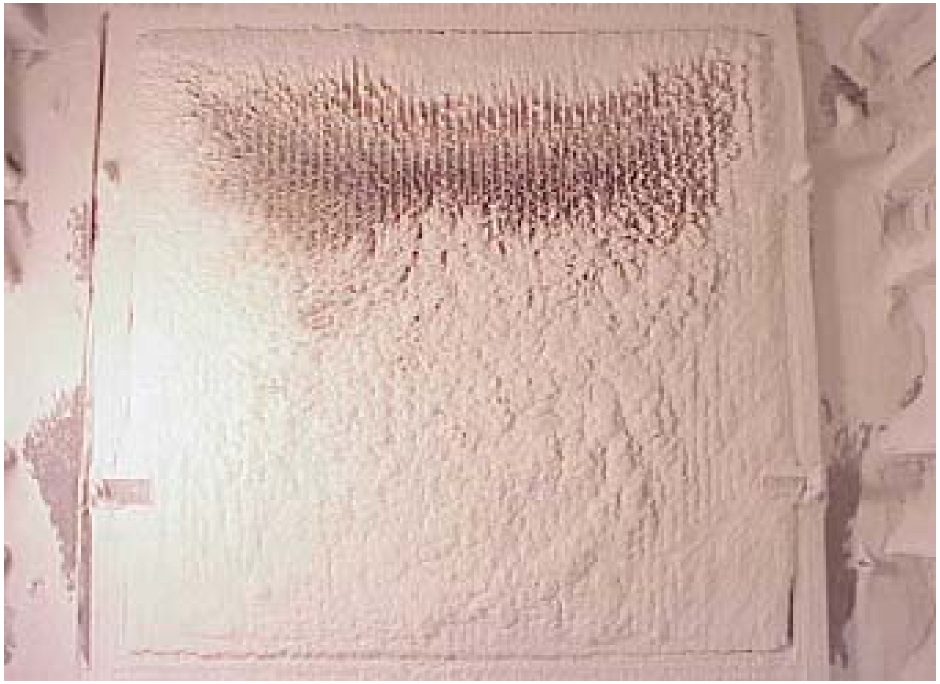
Moving Louvers upstream of core

Passive fan rotating at core face

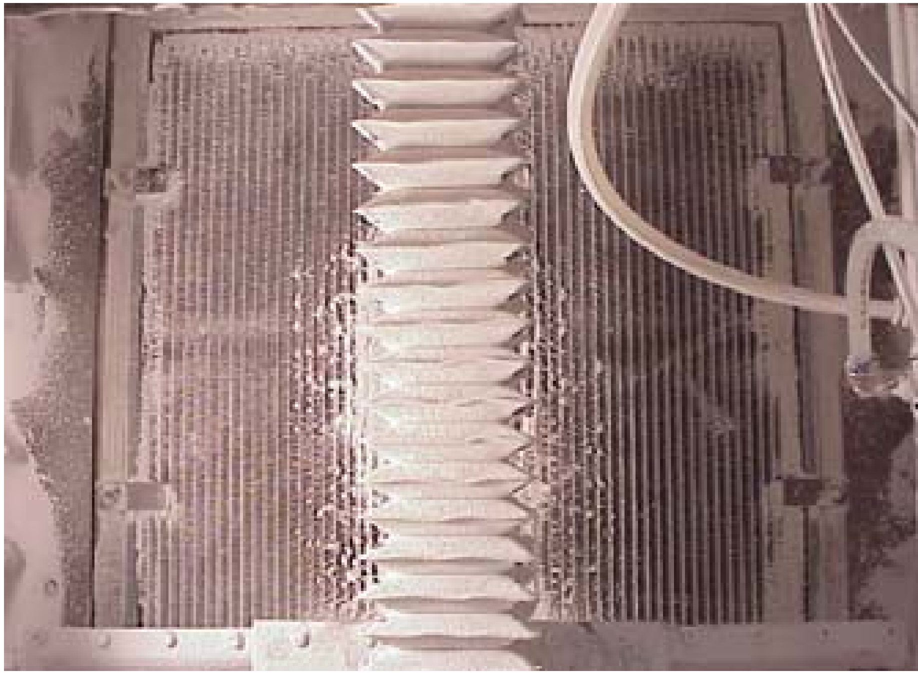
Filtration and electronic means not effective at preventing dust buildup on core face

Cooling Fan and System System Performance and Efficiency Improvements

Technologies Evaluated in Conjunction with *Innoventor, Inc.* of St. Louis, Mo.



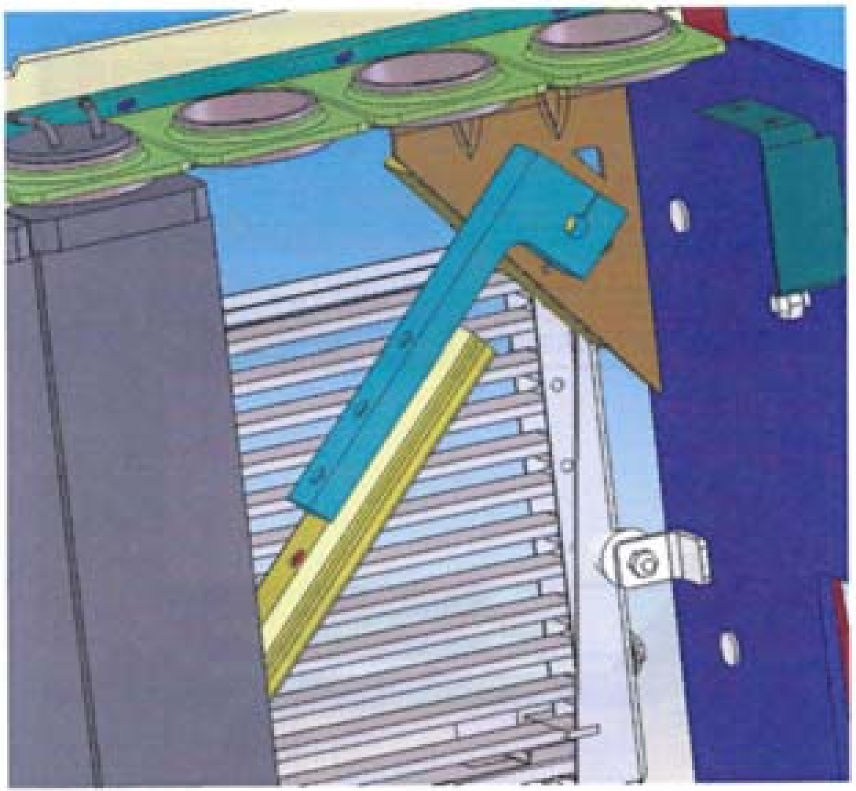
No protection after 44 hours

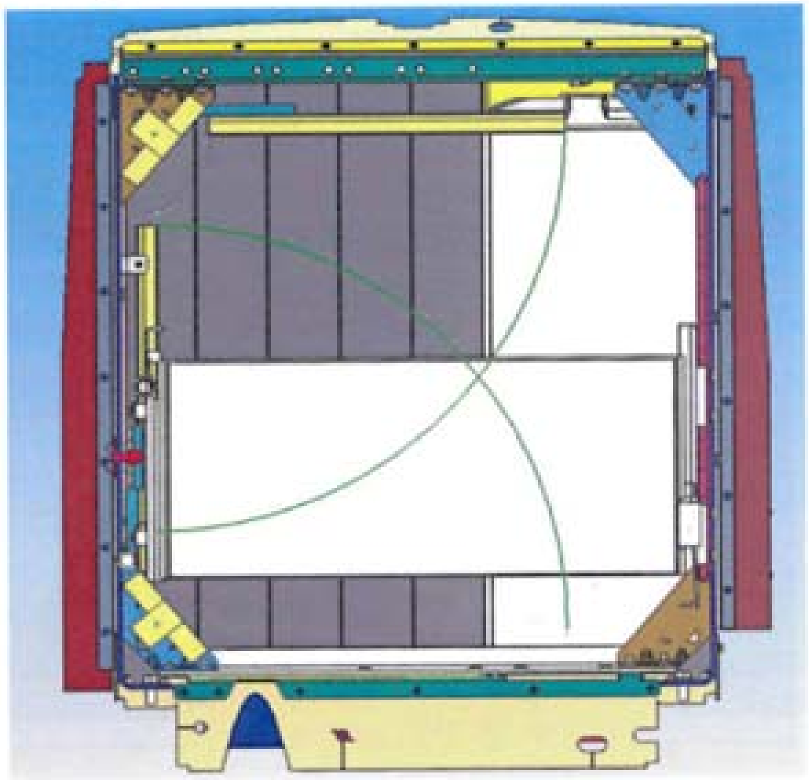


Air knife after 126 hours

Air knife provides energy to blow debris through core!

Actuator Configuration

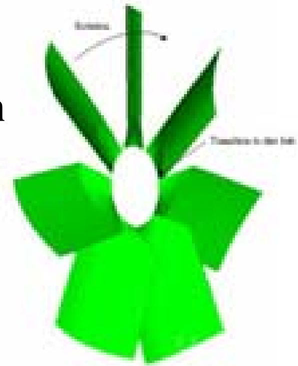




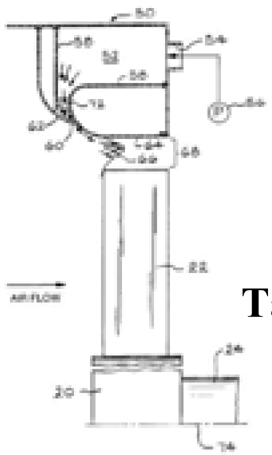
Potential production configuration – inlet screen for organic debris (not shown) with two air knives arranged similar to windshield wipers to sweep the core face.

Cooling Fan and System System Performance and Efficiency Improvements

Task 1 – Large High Performance Axial Fan

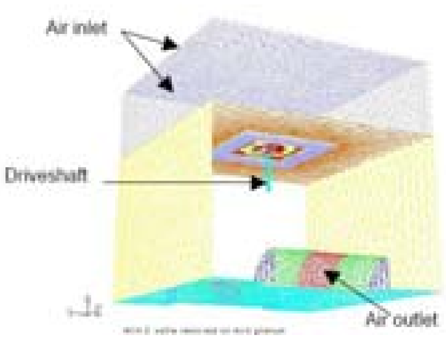


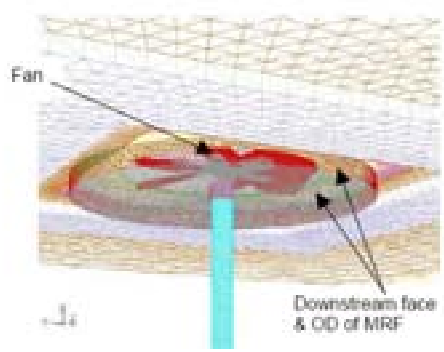
Design and construction details used to design high performance fan for 'More Electric Truck'. Work continues. Currently efficiency 20% better than OEM fan.



Task 2 – "Aeroshroud"

Initial concept from automotive investigations. Will require fan redesign to maximize performance





Incorporated into Caterpillar analysis methods. Allows more, and more accurate, analysis to be completed in the same time frame.

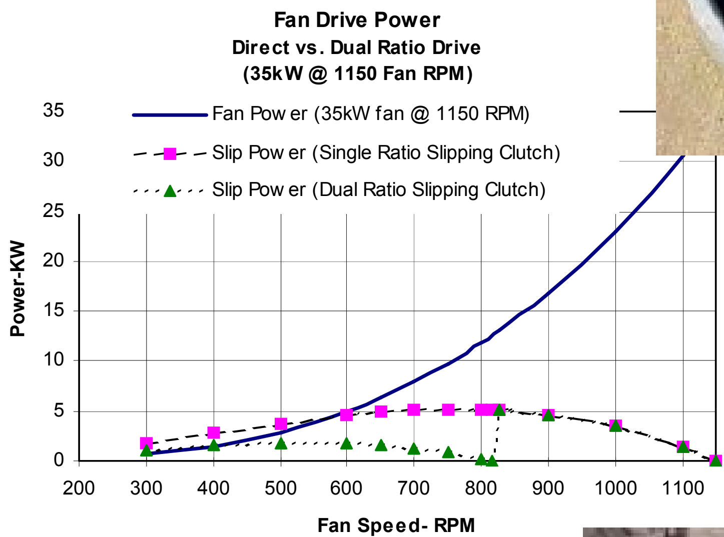
Task 3 – Fan Performance Modeling

Applicability to on-highway world

Cooling Fan and System System Performance and Efficiency Improvements

Task 4 – Small High Performance Fan

Manufacturing complexities and sensitivity to downstream obstructions make this technology unappealing to truck environment



Task 5 – High Efficiency Variable Speed Fan Drive

Dual ratio concept could be very appealing to specific market segments that do not benefit from ram air.

Task 6 – Radiator Debris Filtration

Do not expect significant interest from on-highway world.

Applicability to on-highway world